How do Swiss Universities master the reforms of the last ten years? - Empirical evidence from a data envelopment analysis

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How do Swiss Universities Master the Reforms of the last Ten Years? - Empirical Evidence from a Data Envelopment Analysis

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Abstract

Since the 1990ies the higher education system in the German speaking area has been faced an essential paradigm change: The model of governmental steering and control was replaced by the model of governmental supervision following the concept of New Public Management. It was assumed that an enlargement of autonomy would increase the efficiency of the whole tertiary system. At the same time, the restructuring of the European higher education system has been started in 1999 by implementing the Bologna reforms. To investigate how the Swiss universities have digested the national and international reforms we apply an input distance function and estimate the technical efficiency of a panel data set containing all of the 12 Swiss universities for the period of 1999-2008 both at university level and discipline level. We find essential efficiency variations across the disciplines caused by structural differences regarding the endowment with ressources and output targets which indicate the need to analyse efficiency at a disaggregated level. Furthermore, our results show that there are external determinants that affect the efficiency of Swiss universities.

Preliminary Version (work in progress)

Keywords: Higher Education Production, Efficiency, Tertiary Education Reforms, Bologna Reform

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1 Introduction

Since the 1990ies the higher education system in the German speaking area has been faced an essential paradigm change: The model of governmental steering and control was replaced by the model of governmental supervision following the concept of New Public Management (see e.g. Schenker-Wicki, 2004). Hence, the Swiss Universities were granted more autonomy by the responsible parliaments along with the introduction of global budgeting, performance agreements, and altered reporting. The politicians and the governmental authorities were persuaded that the enlargement of autonomy would increase the efficiency of the whole tertiary system. In this context the term *dividend of autonomy* was introduced as it was assumed that a higher degree of freedom in terms of financing and organizational structuring would allow to manage internal processes more efficiently.

Beside these national reforms the restructuring of the European higher education system has been started in 1999 when signing the Bologna Declaration by 29 European ministries of education. The aim was to establish a common European higher education area by 2010, and to promote the competiveness of higher education in the European countries in order to enhance the economic power and employment in Europe. The European ministries of education met all two years in order to discuss the framework of the Bologna reforms and the process made with respect to developing a system of easily readable and comparable degrees, adopting a system based on three cycles, i.e. at Bachelor, Master's and Doctoral level, enhancing the student and academic mobility and improving the quality to secure high standards of the higher education in Europe.[1] Indeed, Switzerland is one of the countries in Europe which has implemented the Bologna reforms rapidly.[2] Recent extrapolations show that more than 95% of the students will be enrolled in the new Bachelor and Master's degrees until 2010-2011 (Stocktaking, 2007).

After all, to investigate how the Swiss universities have digested the national and international reforms we employ a data envelopment analysis (DEA) and estimate the technical efficiency[3] of all 12 Swiss universities for

[1]For more details see the Bologna Declaration (1999) and the Communiqués of Prague (2001) and Berlin (2003).

[2]Bologna guidelines were issued for universities by the Swiss University Conference (SUK) in 2003 and those for universities of applied sciences and teacher education, respectively, by the Swiss Conference of Cantonal Ministers of Education (EDK in 2002 and 2005.

[3]The efficiency measurement goes back to Koopmans (1951), Debreu (1951), and Farrell (1957) who introduced the concept of technical efficiency; whereas technical efficiency is defined as a firm's ability to produce a given output with a minimum of its inputs or to

the period of 1999-2008. Contrary to other studies, we apply the efficiency analysis at a disaggregated level to account explicitly for heterogenous higher education production. In this regard, the data set includes detailed information on input and output measures such as expenditures, academic and non-academic personnel, enrolled students, doctoral students and research funds differentiated for four disciplines: humanities and social sciences, natural sciences, technical sciences and finally medicine. Furthermore, we are interested in getting information of possible *drivers* which may have an impact on the efficiency of higher education production. Applying a two-stage approach the DEA efficiency scores obtained in the first stage are then used as dependent variable in a truncated regression in a second stage. This will be done in order to get some evidence on steering instruments which could be considered to make higher education production more efficient by both the university management and the governmental authorities.

Section 2 discusses theoretical aspects of the production of higher education and summarizes previous research on the performance of universities. The estimation approach along with the model specifications and methodology are introduced in Section 3. Section 4 provides information on the data set and the modelling approach used for our analyses. Estimation results of the efficiency analyses and the regressions are presented in Section 5.

2 Theoretical Background and Previous Research

Public authorities that decide on the allocation of financial resources are reliant on information such as performance measures to secure effective and efficient employment of financial resources. The relationship between a public authority (principal) and university personnel (agent) can be modeled in a principal-agent framework assuming information assymmetry due to the divergence of interests (see e.g. Kivistö, 2005). With respect to that the problem of moral hazard it is a known phenomenon and can become a problem for a government principal. The pursue of private interest by the agent can be transfered to higher education institutions if they actively promote their own objectives at the expense of public funds. To overcome the problem of moral hazard the principal can either try to discover the agent's behaviour by investing in monitoring procedures (behaviour-based contract) or it can contract on the outcomes of the agent's behaviour (outcome-based contract) - following the concepts of New Public Managment.

maximize its output given a fix level of inputs.

In this respect, the significance of applying analyses based on benchmarks and efficiency measurements in the higher education sector has become more important in recent years which can be seen by an increasingly number of efficiency studies focusing on the tertiary eduction sector. As those techniques allow the performance comparison of several decision making units against a benchmark efficiency analyses provide university management as well as policy makers valuable information on efficient production. In paritular, this might be even more relevant with respect to tight public budgets.

An interesting result of prior studies which supports the term *dividend of autonomy*, stated right in the beginning of the paper, is that the assumption appears to be confirmed that restrictive regulations and productivity are negatively related. Universities are more efficient, the more autonomy is guaranteed by authorities (see e.g. Aghion et al., 2008; Kempkes and Pohl, 2008; Duh and Kuo, 2006).

After all, the higher education sector is characterized by attributes which make it difficult to measure efficiency directly: First of all, higher education is determined by its non-profit nature. Second, there is a lack of price information of many of its inputs and outputs. And third, higher education institutions use multiple inputs to produce multiple outputs.

Moreover, higher education institutions are heterogenous and differ markedly across several disciplines. Assuming that such attributes affect the production function an analysis at the university level would yield to biased efficiency scores. This bias becomes significant in any case the decision making units (DMUs) differ in terms of resource composition and major output targets. For instance, one would suggest that teaching and research is binding more financial and human resources in disciplines such as engineering or medicine (see technical equipment, laboratories, small groups, high student-faculty ratio) than humanities or law. Additionally, it is assumable that acquired third-party funds vary significantly across the disciplines given that some of them, e.g. engineering or economics, are more inclined to receive third party funds than others, e.g. humanities. The same is true for the publication output. Hence, if not accounting for heterogeneous production one will obtain inappropriate performance measures for higher education institutions.

Studies which explicitely account for heterogeneity of higher education production analyse efficiency at the discipline level across a sample of universities, as Bonaccorsi et al. (2006) and Agasisti and Salerno (2007) applied for Italy and Filippini and Lepori (2007) for Switzerland by including humanities, natural as well as technical sciences and medicine. Further studies account for discipiline specific production by a rough differentiation between rather science related (engeeniering, medicine) than arts related disciplines (humanities). Coelli et. al, McMillan and Chan (2006) as well as Stevens (2005) proceeded in that manner for universities in Australia, Canada and the United Kingdom. Moreover, other studies focus on particular chosen academic departments: Madden et al. (1997) estimate efficiency for departments of economics in Australia and Beasly for departments of chemistry and physics in the United Kingdom; for Germany, Warning (2004), Fandel (2003) and Backes-Gellner and Zanders (1989) studied efficiency of specific departments and subject groups of and across German universities. After all, the findings show the significance to measure efficiency at a disaggregated level and not at the university level as a whole since the production technology for different disciplines vary a lot and would – if not doing so – provide biased results.

3 Estimation Approach and Methodology

In order to analyze the performance of Swiss universities, we use an input distance function approach. As we consider a higher education institution, a department or any other decision making unit as a production unit that decides about the use of several inputs such as financial and human resources as well as physical infrastructure to produce at least two outputs, that is teaching and research, under specific optimization conditions the distance function approach proposed by (Shephard, 1953, 1970) seems appropriate. In contrast to other representations, it allows us to describe a multi-input, multi-output production technology without any underlying assumptions on specific behavioral objectives (e.g. cost minimization or profit maximization).

To identify inefficiencies either on the input side or on the output side the distance function approach can be employed assuming input orientation or output orientation. While an input orientation supposes the minimization of inputs given an output determined by exogenous factors an output orientation supposes the maximazitation of outputs holding inputs fixed. For higher education institutions, both perspectives can be appropriate.

An output orientation might appear reasonable if inputs of public higher eduation institutions are decided upon by governmental authorities. Then, universities are modeled as output maximizing institutions. A rather policy-driven argument may also support the output-orientated approach. Against the background of aging societies in the industrialized countries the labour market demand is still immanent for young, highly qualified people. Hence, a public interest that focus on an increase of the number of university graduates could be present more than ever.

Instead, a major aspect in favour of an input orientation is that an output maximising approach may probably lead to inappropriate incentives on the behaviour of universities. One may argue that generally an increase in the number of students and graduates, respectively, might result in a quality decrease of higher education, and hence might decline university's reputation.[4] Another reason which promotes an input-orientated approach is the fact that due to tight governmental budgets the public interest of accountability has also intensified significantly in countries where the tertiary education system is basically funded by public funding.

Therefore, we model the production process by using the input-orientated distance function approach in order to focus on avoidable production inefficiencies at the input side. We are interested in investigating how much the input vector can be proportionally reduced holding the output vector fixed. Following Coelli et al. (2005), the input distance function can be defined as:

$$D_I(x, y) = max\left\{\varphi : (x/\varphi) \in L(y)\right\} \tag{1}$$

where $L(y)$ represents the set of all non-negative input vectors $x = (x_1, ..., x_K) \in R_+^K$ which can produce the non-negative output vector $y = (y_1, ..., y_M) \in R_+^M$. The proportional reduction of the input vector x is measured by φ. φ indicates the distance between an observation located at the frontier and an observation located above the frontier. The function is non-decreasing, linearly homogeneous and concave in x, and non-increasing in y.

In order to estimate the technical efficiency of Swiss universities following the distance functions approach we use the data envelopment analysis (DEA), a method introduced by Charnes et al. (1978). While DEA is a non-parametric method no assumptions are required with respect to the functional relationship of inputs and outputs, i.g. based on a linear programming approach DEA envelopes the observed data as tightly as possible without requiring any functional assumptions on the production process. Instead, it uses the input and output data themselves to compute a piece-wise linear production frontier that is formed by the best practice DMU. Then,

[4]This argument may not be eligible for Switzerland due to the fact that there is a very efficient system of internal and external quality assurance implemented by every single university and supervised by the Center of Accrediation and Quality Assurance of the Swiss Universities. For more details see `http://www.oaq.ch/pub/en/01_00_00_home.php`

the efficiency is estimated according to the relative position and distance, respectively, to the production frontier.

Since the DEA provides only point estimators calculated within a finite sample, the efficiency scores obtained are highly sensitive to sampling variations, errors and other *noise* in the data, and lack common statistical properties. As a result all deviations from the identified production frontier can then be interpreted as inefficient production. In order to overcome this shortcoming, we apply a bootstrap procedure, introduced by Efron (1979). It is used when the original sampling distribution of the estimator of interest, e.g. the efficiency measures, is unknown. In order to correct for biases evoked by the sampling size we compute a bootstrap procedure further developed by Simar and Wilson (1998, 2000*a*,*b*) for non-parametric estimation techniques with B=2000 replications.[5]

The production frontier can be estimated either under constant returns to scale (CRS) or under variable returns to scale (VRS). The CRS approach suggests that all firms can alter their size, and consequently firms of suboptimal size are identified as inefficient (see e.g. Charnes et al., 1978). In contrast, the VRS approach compares firms of similar size while considering efficiency variation basically due to the scale differences (see e.g. Färe et al., 1983; Banker et al., 1984). The latter approach on the one hand is often used when the firm size cannot be influenced directly by the management which we assume to be true for universities. Further, it allows us to account for a possible impact of scale efficiency on the obtained efficiency scores. Due to that, we apply a production frontier with variable returns to scale.

Then, the technical efficiency is estimated separately for each discipline across the universities in our sample. Assuming that the universities use K inputs and M outputs the VRS input-oriented frontier is calculated by solving the following linear optimization program for each of N observations:

$$
\begin{aligned}
& min_{\theta,\lambda}\theta, \\
& s.t. \qquad -y_i + Y\lambda \geq 0, \\
& \qquad\qquad \theta x_i - X\lambda \geq 0, \\
& \qquad\qquad N1'\lambda = 1, \\
& \qquad\qquad \lambda \geq 0,
\end{aligned} \tag{2}
$$

where θ is a scalar and represents the efficiency score for the i-th university. According to the technical efficiency concept by Farrell (1957)[6] it satisfies

[5]For more details on the bootstrap procedure see Simar and Wilson (1998, 2000*a*,*b*).

[6]The Farrell measures are obtained by taking the reciprocal of the efficiency values by

the condition of $\theta \leq 1$, with a value of one indicating a point located on the production frontier, and hence identified as fully efficient, whereas values between zero and one belongs to inefficient observations using an input vector above the frontier. λ is a Nx1 vector of constants, X is the KxN matrix of inputs and Y the MxN matrix of outputs. The i-th university´s input and output vectors are described by x_i and and y_i, respectively. Finally, the convexity constraint $N1'\lambda = 1$ ensures that an inefficient university is only *benchmarked* against universities of similar size.

Since we are interested in identifying crucial determinants that may affect the efficiency of higher education institutitons we use a two-step procedure: In the first stage we estimate the efficiency scores at the university level and for each of the four disciplines across the Swiss universities while solving the DEA linear programming algorithm. Then, in the second stage we regress the efficiency scores obtained from the first stage on explanatory variables using a truncated regression[7] that can basically be specified as follows:

$$\theta_i = \alpha + \beta Z_i + \epsilon_i, \qquad j = 1, ..., n \tag{3}$$

with α as the constant term, ϵ as the error term and Z_i is a (row) vector of observation-specific explanatory variables for DMU i that we expect is related to the DMU's efficiency score, θ_i, through the vector of parameters β (common for all i) that we need to estimate.

4 Data and Modelling Approach

The data set comprises detailed information on the total of all 12 Swiss universities (ten universities are cantonal ones and two are Swiss federal universities, that are the ETH Zurich and the EPFL Lausanne), throughout the period of 1999 and 2008. These differences in the legal and financial framework have to be considered as possible explanations for efficiency differences between institutions.[8] The data used in this study stem from higher education statistics provided by the Federal Statistical Office in Switzerland. All input and output variables are discipline specific. They are summarized

the Shepard distance function.

[7] We apply a truncated regression model in favour of a tobit regression model - therewith we follow Simar and Wilson 2007 - due to the fact that the efficiency scores obtained from the first stage with a value equal to one do in fact have this efficiency level and are not censored. Instead, the efficiency sores are truncated by one.

[8] We exclude the universities of applied sciences, since they differ considerably in the structure of the curricula as well as in their activities, e.g. research share.

in Table 1. Due to the rather small sample - if using the observations for 12 universities per year - we use a pooled model for the data envelopment analysis assuming each year to be an independent observation.[9]

The inputs used are associated with the university budget and comprise the non-personnel expenditures deflated by the Swiss consumer price index as well as academic (professors, assistant professors, researcher assistants) and non-academic personnel (technical and administrative staff), both measured in full-time-equivalents.[10]

To capture the universities' teaching output we use information on the number of undergraduate students enrolled in Bachelor and Master's programmes as well as the Licentiate programmes which are the former Swiss degree programmes and comparable to a Master's programme. As all data used are at the discipline level, possible compensation effects between the disciplines are excluded. This allows us a better assessing and comparing of the *real* efficiency estimated in our analyses.

The number of Doctoral students as well as the amount of both public and private third-party funds serve as proxy variables for the reasearch output. Third-party funds are a good measure of research performance because they are awarded to people with a successful track record in research production, and hence reflect a kind of 'market' value for research (see e.g. Johnes, 1997; Harman, 2000). As already mentioned, we use public and private research funds for our analysis to get a better picture of the faculty's overall research efforts and to cope with the argument of political determination of public research funding. Some scholars argue that public research funding is, to a large extent, politically determined and an increase in research funds could reflect political priorities rather than an increase in research output. The descriptive statistics on mean, standard deviation, minimum and maximum values of the inputs and outputs variables are given in the Appendix.

[9] As each year is handled as an independent observation the effect of technical development on efficiency (e.g. greater use of new technologies, increased computing power, speedier access to library resources) can not be directly measured, but indirectly by a change in the efficiency scores. This should be beared in mind when interpreting the results.

[10] As with an increasingly number of inputs and outputs the factor combinations of the production process rise exponentially, the number of DMUs shaping the production frontier increase and the probability that most of the DMUs become efficient rises. Hence, it is no longer possible to make a clear distinction between efficient and non-efficient universities. So, Cooper et al. (2006) propose that the underlying sample should be at least three times larger than the total number of inputs and output variables. Dyson et al. (2001) recommend that the number of observations must be at least twice the product of the number of inputs and outputs.

Table 1: *Description of variables used for efficiency and regression analyses*

	variables descriptions
input variables	
NON-PERSEXP_budg	total amount of non-personnel expenditures publily financed by budget in tausend CHF
SCPERS_budg	scientific personnel publicly financed by budget, measured in full-time equivalents
NON-SCPERS_budg	non-scientific personnel publicly financed by budget, measured in full-time equivalents
output variables	
STUD_UNG_tot	total number of stuents enrolled in undergraduate study programmes (BA, MA, Licentiate)
PHD_STUD_tot	total number of stuents enrolled in postgraduate study programmes (Doctoral studies, PhD)
FUNDS_tot	total amount of third-party funds in tausend CHF (BA, MA, Licentiate)
explanatory variables	
propSTUDFAC	student-faculty ratio
propACADEM	proportion of scientfic personnel per personnel in total
propPROF	proportion of professors per scientific personnel
propBAMA	proportion of number of students enrolled in Bachelor and Master's programmes per all undergradute students
STUDDURATION	years of studying
MATQUOTE_cant	cantonal matriculation quota
FOUND	year of university foundation
SIZE	number of undergradutate and postgraduate students enrolled
GDP_cant	cantoal GDP per capita
MED	dummy variable for universities operating a hospital
SPECIAL	dummy variable for universities offering specifically study programmes
TIME_trend	time trend

As can be seen from Table 2 both the inputs and outputs cover a wide range of data values which differ substantially across the disciplines.

Finally, the choice of output variables is based on other efficiency studies in the area of higher education and on the availability of data. Generally, we would prefer using graduates (Bachelor, Master, Licentiate) at the discipline level as a proxy for the teaching output instead of students. Unfortunately, there are no such discipline specific data available so far. Especially, efficiency studies for Anglo-Saxon countries use the number of students as an output parameter. This is not crucial because the students are highly selected and the drop out rate is negligible. However, Swiss universities are assigned by law to enroll all people fulfilling the legal requirements to study. In contrast to the Anglo-Saxon system the quota on drop-outs is significantly higher in Switzerland due to the missing selection procedures.

Following Abbott and Doucouliagos (2003) and Carrington et al. (2004) we use alternativly students as teaching output in order to capture the teaching aspect of academia; i.g. teaching is already provided to undergraduate and postgraduate students before they graduate and leave the university. To capture the research output properly we would also have preferably used information on publications and citations[11]; but those data were not available for the whole observation period.

In order to shed light on determinants probably driving university's efficiency we incorporate additional variables (the Z variables) in our analysis which can be differentiated between university characteristics, and environmental characterisics. Thereby, the explanatory variables used can be divided into those which are under control of a university, e.g. the offered range of study programmes as well as the staff and student body assuming implemented selection procedures for both the personnel and students. Determinants which are rather beyond the control of the university management are exogenous factors such as the location of a university or other characteristics such as the regional infrastructure, the system of higher education financing or tertiary education reforms like the Bologna reforms.

For our analysis we do not include variables which capture specifics of the student body because - as already mentioned - Swiss universities are obliged to enroll all people fullfilling the legal requirements for studying. However, if universities have the possibility for student selection, student specifc determinants like sex, foreign origin and social background might be of interest assuming that the student composition may have an effect on efficiency. Instead, as almost 80% of the overall university budget is spent on university personnel and rather to be under control of the university managment we include variables to capture paricularly effects caused by faculty composition. The proportion of scientfic personnel per overall personnel (propACADEM) is used in order to capture an effect of scientific versus non-scientific personnel assuming that universities with an overhead of non-scientific personnel are probably less efficient because there is less time left for teaching and research. The proportion of professors per scientific personnel (propPROF) is also incorporated as proxy variable. One may argue that the higher teaching and research knowledge of a professor compared to a research assistant may have a positive impact on the efficiency. Further, we use the student-faculty ratio (propSTUDFAC) measured as the ratio of students enrolled in undergraduate and Doctoral programmes per

[11] For more details on using publications and citations as output variables see Carrington et al. (2004).

professors publicly financed by university budget because it is often used as an indicator for teaching quality.

Furthermore, we use reform related variables such as the proportion of the number of students enrolled in Bachelor and Master's programmes per all undergradute students (propBAMA) as proxy for the implementation process of new study programmes, and the years of studying (STUDDURATION) in order to control whether a fast implementation of Bachelor and Master's programmes and a reduced study time, respectively, affect efficiency positively. The cantonal matriculation rate is further included (MATQUOTE).

Additionally, we would like to include exogenous factors which are rather beyond the control of university management, but in fact may give reasonable explanations for efficiency variations. So, we use the year of university foundation (FOUND) to capture the reputation of a university assuming that the older a university is the more it has build up a stock of reputation in teaching and research which may have a positive impact on efficiency. Due to the fact that economies of scale may influence the efficiency the total number of undergraduate and postgraduate students enrolled (SIZE) is included as proxy variable. Moreover, the cantonal GDP per capita (GDP_cant) is used as an approximation to capture the impact of possible economic spillovers indicated by a higher GDP. Thereby, the underlying assumptionis is that research intense activities outside the university, such as the existence of labs, research institutions or other think tanks, may affect university efficiency.

Finally, two dummy variables are included: We control for the existence of a hospital (MED) assuming that a university which operates a hospital migth have higher costs which may affect the efficiency negatively. As universities which are specialized with respect to their study programmes - such as ETH Zurich and EPF Lausanne that offer study programmes in the area of technical sciences while the University of St. Gallen and the University of Lucerne only offer study programmes in the area of humanities and social sciences -, one can argue that the more a university is specialized the better it has the ability to concentrate on their strenghts and hence provide teaching and research probably more efficient. Therefore, we use a corresponding dummy variable (SPECIAL). Finally, we incorporate a time variable (TIME_trend) which captures the shift in the technology representing change in technical efficiency.

5 Results

Table 3 shows the results of the technical efficiency values analysed for the Swiss universities throughout the period of 1999 to 2008. For each university the efficiency of the overall production (column 2) and the efficiency of four disciplines, that is humanities and social sciences, natural sciences, medicine, and technical sciences (columns 3-6) are displayed. Generally, efficient production is indicated by values of one, whereas values between zero and one indicate inefficiencies in the production process. Since we apply a bootstrap procedure to correct for biases due to sample size the efficiency values obtained are slightly less than one. Both the bias corrected estimated efficiency values as well as the original estimated efficiency values (in parantheses) are given in Table 3. For instance a value of 0.85 means that the same output could be produced with less than 15% inputs. In other words, a university could become more efficient by 15%.

In alignment with findings in prior studies (see e.g. Schenker-Wicki and Olivares, 2009; Schenker-Wicki and Hürlimann, 2006) our results show relatively high efficiency values for most of the universities in Switzerland. These results indicate, that Swiss universities have mastered the reforms quite well; i.g. it seems that efficient production of higher education was not affected negatively by the additional burden of implementing the national and international reforms. For instance, the overall efficiency values obtained on average are high and nearly stable for the observation period for the University of Zurich as well as the Universities of Lausanne, St. Gallen, Fribourg, Lucerne, Basle and Geneva.

However, analyzing in more detail and looking at the discipline level the picture changes.[12] This is already indicated by the means of the efficiency values obtained for the disciplines: As the mean value at the university level is 0.829 the mean values for the disciplines used for our analysis range between humanities ans social sciences (0.791), natural sciences (0.887), medicine (0.866) and technical sciences (0.952). However, except for the Università della Svizzera Italiana the efficiency estimated at the university as well as at the discipline level has increased, or at least has remained unchanged over time.

In particular, our results show a clear compensation effect if efficiency is assessed at the university level; it seems that a divergence of efficiency values

[12] Due to the fact that the number of observations is different across the disciplines a direct comparison of the efficiency values is not possible. This should be considered when interpreting the results. However, it gives a first clue that the estimation of efficiency at the university level yield to biased efficiency values.

occures through structural differences in the inputs and outputs. Lower efficiency values in various disciplines can be compensated by higher efficiency values in other disciplines. For instance, even though the universities in Fribourg and Lausanne are overall highly efficient and build the benchmark for efficient production at the university level we found lower efficiency values in different areas such as humanities and social sciences. If looking only at the total production level this compensation would be disguised. Particularly, the results for humanities and social sciences show further that the efficiency values are generally lower than in other disciplines. An explanation could be that especially in study programmes of this discipline a teaching capacity is held up in order to deal with the very high number of entry students though the number of students decrease for higher semesters. Another point that should be mentioned if analyzing only the overall production, is the fact that the range of study programms and subjects the universities offer differ broadly. In Switzerland, only the universities of Berne, Basle, Zurich, Geneva and Lausanne are so-called full universities offering a wide range of subjects, whereas other universities offer only a small range of disciplines, e.g. the university of St. Gallen and the university of Lucerne focuse on humanities and social sciences, while the ETH Zurich and EPF Lausanne focus on natural and technical sciences.

Table 4 presents the results of the second-stage truncated regression estimated for the university level (column 2) as well as for the four disciplines (column 3-6) based on the bias corrected DEA efficiency scores obtained from the first stage with the standard error in parantheses. The overall fit of the model specifications is quite good as indicated by the Wald chi^2 and the pseudo R^2. No significant results are found for technical sciences, probably due to the relation of the fairly small number of observations compared to the number of explanatory variables used for the regression.

The results show a mixed pattern exept the variables which capture the student-faculty ratio and faculty composition. As can be seen from Table 4 the student-faculty ratio has a small but highly significant influence on the efficiency at the university-level, and for humanities and social sciences, as well as natural sciences. The result indicate that the higher the student-facutly ratio the higher the efficiency. Indeed, as this indicator represents teaching quality meaning that the relation of professors per students should be small to assures good teaching, our result imply that teaching quality goes account of efficiency. However, this finding is quite intuitive as an increase of labour inputs, that is the number of professors, comes along with a low student-faculty ratio. Furthermore, the proportion of professors per scientific personnel has also a significant positiv effect on the efficiency at the university-level, and for humanities and social sciences, as well as medical sciences which may be due to higher knowledge and skills in teaching and research. Especially, for medical sciences this might be plausible as professors in this area has to be state-of-the-art with respect to newest research and treatment techniques. For natural sciences we also find a positive significant influence of faculty composition, too; that is the more scientific personnel the higher the efficiency which imply that in this area a high overhead account of teaching and research activities and hence decrease efficiency.

Moreover, we find unambiguous or no effects with respect to the stage of implementing new Bachelor and Master's programmes and the duration of study. Only for humanities and social sciences there is a positiv significant effect which means that the more study programmes already designed as Bachelor and Master's degrees the higher the university efficiency. This is probably due to the fact that it is the largest area with respect to the number of students enrolled compared to the other disciplines, and hence the faster the implementation process of the new study programmes the better. Further, a reduced study time - as we assumed - has a postive impact on the efficiency for humanities and social sciences as well as at the university level. Besides, for natural sciences the effect is the opposite which we cannot explain so far.

With respect to institutional specifics we find no reputation effect of older universities on efficiency but a positive though small size effect which could be explained with the existence of economies of scale. Additionally, no effects can be found when controlling for the existence of a hospital and a specialized offering of subjects at the university level. Moreover, there are unambiguous results for natural and medical sciences concerning the cantonal GDP which we could not explain so far. Finally, a negativ significant time trend is identified for humanities and social sciences. Independent of the negative sign that implies regressive technical change, the fairly low magnitude suggests almost no technical change for the universities in our sample. This result can be explained by the very limited possibilities of the higher education institutions to benefit from labor or capital-saving technological improvements which can be find in other sectors.

Summing up, we find that differences between disciplinary groups are to some extent larger than differences between universities. Due to the markedly efficiency variation across the disciplines, efficiency has to be analyzed on a disaggregated level and not at the university level. Otherwise the efficiency values are biased, and therefore inappropriate for evidence-based decision making. Moreover, our regression analyses show that there are determinants that have an impact on the efficiency of Swiss universities. However, further analyses will be carried out to consolidate the findings. This will be done in order to get some more evidence on the steering instruments which could be used to make higher education production more efficient by both the university management and the governmental authorities.

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Appendix

Table 2: *Descriptive statistics of input and output variables*

discipline (obs) variable	mean	sd	min	max
uni-total (120)				
non-persexp_budg	103159.8	93491.91	1384.281	386098.8
scpers_budg	1118.743	893.8452	33.25	3353.13
nonscp_budg	713.4254	610.0981	14.3	2170.28
stud_undg_tot	7190.35	4811.746	164	20330
phd_stud_tot	1332.492	937.1336	29	3793
funds_tot	81143.68	53903.8	494.131	199840.7
humanities and social sciences (107)				
non-persexp_budg	9166.377	10838.21	362.4849	44122.63
scpers_budg	433.0408	312.245	33.2503	1280.9
nonscp_budg	88.5986	83.91224	0.25	476.3
stud_undg_tot	5418.589	4129.776	164	16185
phd_stud_tot	627.6168	496.411	1	2063
funds_tot	18438.64	14316.25	494.131	74112.34
natural sciences (95)				
non-persexp_budg	19710	17874.01	33.45228	67502.16
scpers_budg	408.7037	355.953	3.75	1512.7
nonscp_budg	198.1358	137.8536	1.5	594.05
stud_undg_tot	1287.779	945.8244	47	3836
phd_stud_tot	503.3368	339.5701	8	1586
funds_tot	30369.18	17588.14	14.81374	80180.7
technical sciences (38)				
non-persexp_budg	16147.42	15722.9	359.1644	45551.07
scpers_budg	559.3764	608.0413	21.18	1599.79
nonscp_budg	191.7779	193.2858	6.5	525.31
stud_undg_tot	1948.231	1981.514	8	5130
phd_stud_tot	483.8462	493.9047	5	1471
funds_tot	35290.33	29346.98	148.8284	81498.22
medicine (63)				
non-persexp_budg	56382.02	55338.51	1975.743	169642.8
scpers_budg	387.6703	246.6299	45.56	969.8099
nonscp_budg	325.6625	263.0664	16.3	922.91
stud_undg_tot	1235	533.5021	295	2203
phd_stud_tot	432.8833	245.1983	74	923
funds_tot	43738.13	25811.57	2055.147	85944.03

(*monetary values are deflated and displayed in tausend Swiss Francs)

Table 3: *Efficiency values of Swiss universities 1999-2008*

uni_year	uni-total	humanities and social sciences	natural sciences	medicine	technical sciences
	bias corr eff (original eff)	bias corr eff (original eff)	bias corr eff (original eff)	bias corr eff (original eff)	bias corr eff (original eff)
BS_99	0.781	0.771	0.727	0.958	
	(0.820)	(0.794)	(0.747)	(1.000)	
BS_00	0.696	0.737	0.747	0.959	
	(0.727)	(0.772)	(0.770)	(1.000)	
BS_01	0.693	0.692	0.730	0.871	
	(0.722)	(0.718)	(0.747)	(0.883)	
BS_02	0.871	0.819	0.926	0.948	
	(0.903)	(0.851)	(0.947)	(0.969)	
BS_03	0.942	0.872	0.966	0.949	
	(1.000)	(0.906)	(0.993)	(1.000)	
BS_04	0.949	0.822	0.966	0.960	
	(0.986)	(0.861)	(1.000)	(0.978)	
BS_05	0.938	0.816	0.950	0.976	
	(1.000)	(0.853)	(1.000)	(1.000)	
BS_06	0.918	0.852	0.946	0.938	
	(1.000)	(0.890)	(1.000)	(1.000)	
BS_07	0.941	0.861	0.926	0.965	
	(1.000)	(0.906)	(0.955)	(1.000)	
BS_08	0.924	0.892	0.945	0.944	
	(1.000)	(0.943)	(1.000)	(1.000)	
BE_99	0.756	0.684	0.958	0.674	
	(0.783)	(0.710)	(1.000)	(0.681)	
BE_00	0.663	0.674	0.924	0.640	
	(0.684)	(0.697)	(0.944)	(0.649)	
BE_01	0.664	0.700	0.895	0.677	
	(0.688)	(0.724)	(0.918)	(0.684)	
BE_02	0.707	0.802	0.910	0.672	
	(0.736)	(0.822)	(0.940)	(0.681)	
BE_03	0.842	0.933	0.933	0.796	
	(0.867)	(0.966)	(1.000)	(0.802)	
BE_04	0.804	0.886	0.940	0.759	
	(0.839)	(1.000)	(1.000)	(0.767)	
BE_05	0.707	0.821	0.868	0.702	
	(0.738)	(0.852)	(0.894)	(0.711)	
BE_06	0.822	0.904	0.946	0.850	
	(0.849)	(0.946)	(0.975)	(0.860)	
BE_07	0.829	0.869	0.935	0.939	
	(0.864)	(0.916)	(0.960)	(0.956)	
BE_08	0.821	0.802	0.935	0.949	
	(0.864)	(0.861)	(1.000)	(1.000)	
FR_99	0.958	0.769	0.635		
	(0.996)	(0.806)	(0.651)		
FR_00	0.953	0.803	0.619		
	(1.000)	(0.830)	(0.635)		
FR_01	0.943	0.875	0.761		
	(0.980)	(0.901)	(0.776)		
FR_02	0.921	0.885	0.764		
	(1.000)	(0.914)	(0.782)		
FR_03	0.932	0.826	0.830		
	(1.000)	(0.858)	(0.850)		
FR_04	0.934	0.871	0.842		
	(1.000)	(0.899)	(0.861)		
FR_05	0.958	0.855	0.920		
	(1.000)	(0.882)	(0.938)		
FR_06	0.966	0.819	0.937		
	(1.000)	(0.847)	(0.961)		
FR_07	0.945	0.767	0.946		
	(0.993)	(0.802)	(0.970)		
FR_08	0.933	0.745	0.938		
	(1.000)	(0.786)	(1.000)		
GE_99	0.802	0.645	0.623	0.974	0.872
	(0.833)	(0.663)	(0.637)	(1.000)	(0.887)
GE_00	0.820	0.727	0.602	0.949	0.857
	(0.858)	(0.770)	(0.618)	(1.000)	(0.872)

uni_year	uni-total	humanities and social sciences	natural sciences	medicine	technical sciences
	bias corr eff (original eff)	bias corr eff (original eff)	bias corr eff (original eff)	bias corr eff (original eff)	bias corr eff (original eff)
GE_01	0.883 (0.932)	0.768 (0.815)	0.571 (0.588)	0.937 (1.000)	0.979 (1.000)
GE_02	0.931 (1.000)	0.825 (0.885)	0.678 (0.695)	0.968 (1.000)	0.967 (1.000)
GE_03	0.884 (0.929)	0.736 (0.780)	0.658 (0.676)	0.923 (0.941)	0.871 (0.891)
GE_04	0.829 (0.868)	0.747 (0.786)	0.778 (0.800)	0.834 (0.848)	0.975 (0.993)
GE_05	0.819 (0.859)	0.828 (0.885)	0.687 (0.704)	0.863 (0.877)	0.965 (1.000)
GE_06	0.899 (1.000)	0.904 (0.994)	0.894 (0.922)	0.935 (0.953)	0.949 (1.000)
GE_07	0.893 (1.000)	0.885 (1.000)	0.841 (0.871)	0.929 (0.947)	0.949 (1.000)
GE_08	0.879 (1.000)	0.763 (0.816)	0.919 (1.000)	0.937 (1.000)	
LS_99	0.946 (1.000)	0.732 (0.769)	0.908 (0.931)	0.950 (1.000)	
LS_00	0.942 (1.000)	0.739 (0.769)	0.954 (1.000)	0.957 (1.000)	
LS_01	0.934 (1.000)	0.719 (0.749)	0.962 (1.000)	0.939 (1.000)	
LS_02	0.926 (0.965)	0.610 (0.643)	0.943 (0.965)	0.974 (1.000)	
LS_03	0.926 (0.961)	0.608 (0.636)	0.943 (1.000)	0.974 (0.990)	
LS_04	0.918 (0.954)	0.650 (0.698)	0.968 (1.000)	0.952 (1.000)	
LS_05	0.906 (0.941)	0.701 (0.746)	0.974 (0.996)	0.942 (0.964)	
LS_06	0.898 (0.929)	0.789 (0.842)	0.884 (0.905)	0.975 (1.000)	
LS_07	0.915 (0.950)	0.923 (1.000)	0.920 (0.942)	0.971 (0.996)	
LS_08	0.947 (1.000)	0.920 (0.986)	0.937 (0.960)	0.934 (1.000)	
LU_99	0.887 (1.000)	0.779 (0.852)			
LU_00	0.889 (1.000)	0.862 (1.000)			
LU_01	0.771 (0.818)	0.689 (0.745)			
LU_02	0.869 (0.926)	0.848 (0.914)			
LU_03	0.946 (1.000)	0.951 (1.000)			
LU_04	0.944 (0.994)	0.944 (0.994)			
LU_05	0.901 (1.000)	0.935 (1.000)			
LU_06	0.913 (1.000)	0.935 (1.000)			
LU_07	0.876 (0.929)	0.856 (0.900)			
LU_08	0.937 (1.000)	0.776 (0.812)			
NE_99	0.685 (0.719)	0.516 (0.544)	0.802 (0.827)		0.768 (0.790)
NE_00	0.794 (0.839)	0.479 (0.503)	0.971 (1.000)		0.950 (1.000)
NE_01	0.647 (0.687)	0.618 (0.641)	0.969 (1.000)		0.949 (1.000)
NE_02	0.771 (0.803)	0.677 (0.702)	0.923 (1.000)		0.949 (1.000)
NE_03	0.883 (0.910)	0.702 (0.739)	0.928 (1.000)		0.967 (1.000)
NE_04	0.727	0.717	0.862		0.835

uni_year	uni-total	humanities and social sciences	natural sciences	medicine	technical sciences
	bias corr eff (original eff)	bias corr eff (original eff)	bias corr eff (original eff)	bias corr eff (original eff)	bias corr eff (original eff)
	(0.755)	(0.747)	(0.890)		(0.861)
NE_05	0.801	0.766	0.956		0.959
	(0.828)	(0.799)	(1.000)		(1.000)
NE_06	0.750	0.807	0.943		0.913
	(0.783)	(0.847)	(1.000)		(0.940)
NE_07	0.756	0.764	0.957		0.950
	(0.787)	(0.801)	(0.987)		(1.000)
NE_08	0.738	0.717	0.923		0.948
	(0.768)	(0.752)	(0.954)		(1.000)
SG_99	0.890	0.855			
	(1.000)	(1.000)			
SG_00	0.936	0.885			
	(1.000)	(0.980)			
SG_01	0.951	0.860			
	(1.000)	(1.000)			
SG_02	0.933	0.851			
	(1.000)	(0.910)			
SG_03	0.948	0.865			
	(1.000)	(0.928)			
SG_04	0.934	0.870			
	(1.000)	(1.000)			
SG_05	0.869	0.859			
	(0.919)	(0.933)			
SG_06	0.851	0.794			
	(0.905)	(0.871)			
SG_07	0.914	0.856			
	(1.000)	(1.000)			
SG_08	0.881	0.857			
	(1.000)	(1.000)			
UZH_99	0.929	0.948	0.858	0.937	
	(0.971)	(1.000)	(0.874)	(1.000)	
UZH_00	0.953	0.932	0.848	0.939	
	(1.000)	(0.985)	(0.865)	(1.000)	
UZH_01	0.920	0.928	0.875	0.939	
	(0.966)	(1.000)	(0.891)	(1.000)	
UZH_02	0.936	0.908	0.919	0.954	
	(1.000)	(1.000)	(0.935)	(1.000)	
UZH_03	0.904	0.874	0.944	0.937	
	(1.000)	(1.000)	(0.960)	(1.000)	
UZH_04	0.935	0.919	0.949	0.937	
	(1.000)	(1.000)	(0.967)	(1.000)	
UZH_05	0.949	0.920	0.955	0.968	
	(1.000)	(1.000)	(0.978)	(0.991)	
UZH_06	0.946	0.892	0.942	0.937	
	(1.000)	(1.000)	(0.963)	(1.000)	
UZH_07	0.935	0.894	0.958	0.964	
	(0.999)	(1.000)	(0.993)	(0.983)	
UZH_08	0.878	0.860	0.946	0.937	
	(1.000)	(1.000)	(1.000)	(1.000)	
USI_99	0.913				
	(0.962)				
USI_00	0.919	0.859			
	(1.000)	(1.000)			
USI_01	0.884	0.848			
	(0.928)	(0.925)			
USI_02	0.737	0.915			
	(0.765)	(0.978)			
USI_03	0.676	0.907			
	(0.700)	(0.946)			
USI_04	0.744	0.826	0.920		
	(0.770)	(0.864)	(1.000)		
USI_05	0.624	0.689	0.924		
	(0.654)	(0.719)	(1.000)		
USI_06	0.662	0.675	0.922		
	(0.684)	(0.703)	(1.000)		
USI_07	0.657	0.639	0.937		
	(0.681)	(0.672)	(1.000)		

uni_year	uni-total	humanities and social sciences	natural sciences	medicine	technical sciences
	bias corr eff (original eff)	bias corr eff (original eff)	bias corr eff (original eff)	bias corr eff (original eff)	bias corr eff (original eff)
USI_08	0.596 (0.630)	0.617 (0.654)	0.921 (1.000)		
EPFL_99	0.605 (0.641)		0.941 (0.964)		0.958 (1.000)
EPFL_00	0.599 (0.625)		0.849 (0.878)		0.970 (1.000)
EPFL_01	0.580 (0.610)		0.945 (1.000)		0.892 (0.915)
EPFL_02	0.675 (0.715)		0.921 (0.951)		0.953 (1.000)
EPFL_03	0.744 (0.793)		0.954 (1.000)		0.953 (1.000)
EPFL_04	0.666 (0.703)		0.958 (0.989)		0.965 (1.000)
EPFL_05	0.619 (0.644)		0.866 (0.887)		0.963 (0.989)
EPFL_06	0.589 (0.614)		0.789 (0.809)		0.975 (1.000)
EPFL_07	0.657 (0.688)		0.792 (0.822)		0.966 (1.000)
EPFL_08	0.683 (0.720)		0.950 (1.000)		0.949 (1.000)
ETHZ_99	0.614 (0.641)		0.918 (0.942)	0.943 (1.000)	0.972 (1.000)
ETHZ_00	0.560 (0.582)		0.902 (0.925)	0.967 (1.000)	0.906 (0.923)
ETHZ_01	0.585 (0.607)	0.470 (0.503)	0.955 (1.000)	0.838 (0.856)	0.916 (0.930)
ETHZ_02	0.644 (0.671)	0.611 (0.645)	0.926 (1.000)	0.946 (1.000)	0.896 (0.911)
ETHZ_03	0.818 (0.857)	0.752 (0.788)	0.935 (1.000)	0.939 (0.963)	0.829 (0.847)
ETHZ_04	0.667 (0.706)	0.639 (0.666)	0.962 (0.998)	0.913 (0.930)	0.822 (0.839)
ETHZ_05	0.681 (0.725)	0.766 (0.797)	0.960 (1.000)	0.796 (0.813)	0.871 (0.893)
ETHZ_06	0.846 (0.888)	0.636 (0.662)	0.934 (0.971)	0.973 (1.000)	0.948 (0.973)
ETHZ_07	0.880 (0.947)	0.509 (0.533)	0.925 (1.000)	0.873 (0.892)	0.935 (0.960)
ETHZ_08	0.878 (1.000)	0.628 (0.662)	0.921 (1.000)	0.970 (0.990)	0.949 (1.000)

(*Farrell efficiency values are displayed; No efficiency values indicate that at least one of the output variables has values of zero
All estimations are made with FEAR: A package for frontier efficiency analysis with R (Wilson, 2005).)

Table 4: *Truncated, second-stage regression of the efficiency scores*

	uni-total	humanities and social sciences	natural sciences	medicine	technical sciences
propSTUDFAC	0.00***	0.00***	0.01***	0.01	0.00
	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)
propACADEM	0.33	0.00	0.04***	0.00	-0.01
	(0.21)	(0.00)	(0.01)	(0.02)	(0.04)
propPROF	1.13***	1.23***	-0.67	0.87**	-0.84
	(0.21)	(0.20)	(0.60)	(0.33)	(1.22)
propBAMA	-0.02	0.20***	0.07	-0.01	0.07
	(0.06)	(0.05)	(0.07)	(0.08)	(0.05)
STUDDURATION	-0.10***	-0.02**	0.11***	-0.01	-0.00
	(0.02)	(0.01)	(0.02)	(0.03)	(0.02)
MATQUOTE_cant	-0.01*	-0.00	0.01	0.03***	0.01
	(0.00)	(0.00)	(0.01)	(0.01)	(0.01)
FOUND	-0.00	-0.00	-0.00	0.00	0.00
	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)
SIZE	0.00***	0.00***	-0.00	0.00	0.00
	(0.00)	(0.00)	(0.00)	(0.00)	(0.00)
GDP_cant	0.00	0.00	-0.00*	0.00**	-0.01
	(0.00)	(0.00)	(0.00)	(0.00)	(0.01)
MED	-0.03				
	(0.08)				
SPEC	-0.06				
	(0.03)				
time_trend	0.01	-0.02**	0.01	0.00	0.02*
	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)
constant	0.93***	0.44**	0.35	-0.69	2.12*
	(0.30)	(0.13)	(0.34)	(0.46)	(1.02)
sigma_cons	0.08***	0.07***	0.08***	0.06***	0.05***
	(0.01)	(0.01)	(0.01)	(0.01)	(0.01)
log likelihood	166.63	141.3	146.71	109.15	75.73
Wald chi^2	158.54	148.91	54.34	58.74	14.03
(Pseudo-R2)	0.6570	0.6025	0.5185	0.6541	0.3637
No. of observations	120	107	95	63	38

(*, ** and *** denote significance levels 10%, 5% and 1%; standard erros in parentheses)